

## **Safety and Technology Status of the Infrastructure Supporting Hydrogen Fuels Transportation**

The Department of Transportation (DOT) is responsible for the safety of the infrastructure supporting hydrogen fuels transportation and of the vehicles used by industry and the public. DOT's role includes establishing hazardous materials regulations to ensure the safe transportation of hydrogen, specifically those governing both hydrogen delivery and storage systems incident to transportation. DOT leads Federal efforts to ensure vehicle safety through the establishment of the Federal Motor Vehicle Safety Standards and International Global Technical Standards.

As discussed in the following assessment, DOT, working with DOE, will conduct R&D to help mitigate the likelihood of a hydrogen transportation incident through development of safety codes, standards and regulations. This R&D will also help DOT address any safety gaps between continuing advances in technology and regulatory requirements. DOT will support a safe hydrogen economy through efforts to develop and demonstrate advanced technologies for light, medium and heavy-duty vehicles. DOT and DOE, will prepare communities and emergency responders for incidents involving hydrogen fuels transportation should they occur through a comprehensive safety training and educational effort developed with the National Association of State Fire Marshals and the Volpentest HAMMER Training and Education center.

### ***Status of Existing Infrastructure Technology for Hydrogen Transportation***

Until recently, hydrogen has been principally viewed as a commodity used by industry for petrochemical, metallurgical and semiconductor applications, food preparation, and the space program. Under the existing infrastructure, U.S. industry has extensive experience in handling and transporting hydrogen safely as a flammable gas in quantities and forms used to support industrial purposes.

Current hydrogen infrastructure and related technologies have been adequate to support the demand for industrial applications of hydrogen. Hydrogen for these purposes is produced primarily from natural gas and transported via the Nation's hydrogen pipelines. There are several hundred miles of hydrogen pipelines in areas of the U.S. where large refineries are located and industrial chemicals produced. Hydrogen is also transported in commerce by highway and rail, and depending on its form-liquid or gas-it can be transported in DOT specification cylinders, highway cargo tanks and tube trailers, rail tank cars and/or cryogenic liquid tanks (by highway or rail). Transportation of hydrogen in cylinders and tube trailers typically has a range of 100 to 200 miles from the production or distribution facility. For distances up to 1,000 miles, hydrogen is transported as a liquid in DOT-approved cryogenic tanks and then vaporized for use at the customer site. Often, production facilities will use these packages for storing hydrogen when not in transport. DOT leads Federal efforts to explore fuel cell applications in trucks, buses and marine vessels. There are a small, but growing, number of demonstrations of hydrogen-fueled buses and passenger vehicles that include fueling station infrastructure, most notably in California.

RSPA has a significant role within DOT in regulating the transport of hydrogen and ensuring its safety. When transported in the Nation's pipelines, hydrogen is regulated by RSPA's Office of Pipeline Safety (OPS). OPS maintains a comprehensive set of codes and standards for gas and hazardous liquids transport and distribution to assure a high safety level for the Nation's pipeline system. When transported in commerce by modes other than in pipelines, hydrogen is regulated by RSPA's Office of Hazardous Materials Safety because hydrogen--a flammable gas--is designated as a hazardous material. All hazardous materials transported in commerce are governed by a comprehensive set of regulations known as the Hazardous Materials Regulations (HMR), promulgated by RSPA. The HMR address hazardous materials classification, packaging, hazard communication, training, and operational rules. In addition to RSPA, the regulations are enforced by the respective DOT Operating Administrations with modal responsibilities for highway, rail, water and air. The HMR have enabled industry to transport hydrogen safely for many years without serious incidents and have helped ensure the public's confidence in transportation.

### ***Safety and Technology Developments Needed for Future Hydrogen Transportation Infrastructure***

The success of the President's vision for a hydrogen economy will rely largely on the ability of the hydrogen infrastructure to supply needed quantities of hydrogen at competitive costs. It will also rely on having a sufficient demand for fuel cell and hydrogen-powered vehicles. Public acceptance of this new transportation technology will depend on its confidence in the safety of those vehicles and the supporting infrastructure.

The infrastructure to support hydrogen fuels distribution, storage and delivery to hydrogen-powered vehicles will likely evolve in stages from the current hydrocarbon-based economy to a hydrogen-based economy. In the near term, a transition to a hydrogen economy can be expected to rely on an infrastructure that supports on-site production of hydrogen, limited use of natural gas pipelines, and some shipments of hydrogen by highway. Future distribution and delivery systems will be determined by market forces and the technologies to support them.

Ensuring the safety of the infrastructure for transporting, storing and delivering hydrogen will be critical to the success of a hydrogen economy, as demand increases during the transition from industrial to consumer applications. For example, the current DOT packaging system, although appropriate for small-scale use of hydrogen, will require substantial modifications in design and fabrication to accommodate increased hydrogen demand. There is already evidence that even a small variance in demand due to evolving changes in technologies will have significant implications for the existing hydrogen transportation infrastructure. In support of demonstration activities, industry has begun developing new packaging technologies and delivery systems, such as portable refueling vehicles, to increase the efficiency and reduce the cost of hydrogen transport. Many of these technologies involve packaging that uses new materials or operates at increased pressure. RSPA has regulatory responsibility for the validation, testing and certification of such new uses under the HMR, as a prerequisite for deploying them in transportation. DOT is already experiencing an increased need for R&D in order to respond to industry requirements, and this demand is expected to grow in advance of the commercialization of hydrogen-powered vehicles and the expansion of the hydrogen infrastructure.

The evolution of the transportation, delivery and storage systems for hydrogen will transition several times in both the short- and long-term to support a hydrogen economy. The infrastructure to support a hydrogen economy will depend on the technology choices made for transportation and distribution. These choices are, as yet, unknown. R&D results and deployment decisions will play a major role in determining future infrastructure needs and requirements.

In collaboration with the DOE Hydrogen Program's delivery R&D, solutions to address numerous safety issues for transport and handling will be pursued because of hydrogen's wide range of flammability and other general physical behavior. For example, a better understanding is needed of the long-term effect of hydrogen on the strength, fatigue life and ductility of materials proposed for use in pipelines and other infrastructure. Pipeline transmission of hydrogen will require new measures to avoid material embrittlement. Research in new materials such as metal ceramic composites, advanced resins and engineered fibers will also be needed to ensure the integrity and safety of any physical infrastructure for hydrogen fuels.

### **Analysis Of Steps RSPA Is Taking To Work With DOE And To Complement DOE Programs**

DOE is charged with leading broad R&D programs for implementing the President's Hydrogen Fuel Initiative. In its National Hydrogen Energy Roadmap (November 2002), DOE outlined a path for government and industry to overcome an array of technical, economic and institutional challenges for expanding the use of hydrogen-based energy and technologies. DOT and DOE program managers meet periodically to discuss program plans, identify complementary roles in R&D, and define budgets to implement the plan.

RSPA and the other DOT Operating Administrations are working with and complementing DOE programs in a number of ways. DOT's primary areas of focus include:

1. Safety R&D supporting the development of codes, standards and regulations;
2. Safety of infrastructure and vehicle technologies; and
3. Safety education and outreach to foster the acceptance of new and emerging technologies.

### ***Safety R&D Supporting the Development of Codes, Standards and Regulations***

The development of codes and standards is important to ensure that investment in technology development produces usable and safe delivery and storage systems for hydrogen infrastructure. Coordination between DOE and DOT from the early stages of technology development will yield two principal benefits: 1) it will shorten the timeline to introduction by providing information necessary to support the development of regulations concurrently or more quickly; and 2) it will maximize payoffs of DOE R&D by focusing efforts on these technologies up-front on safety issues.

The process of collecting technical information for the development of codes and standards, and validation of related safety issues will also become more effective through close DOT coordination with DOE. DOE has agreed to reimburse RSPA for conducting R&D, participating in codes and standards developing organizations, and performing hazard analyses and risk management for hydrogen transportation and storage systems. DOT involvement in DOE technologies should begin in the initial stage of research to ensure that any chosen technology will also address related safety issues.

RSPA's Office of Hazardous Materials Safety can provide industry with relief from the HMR to foster the use of new and innovative technologies through an exemptions and approvals process. Industry, in the expectation of a market for products to support the hydrogen economy, has begun developing new hydrogen delivery and storage technologies and applications. RSPA has already begun to receive exemption requests from industry for the use of high-pressure, large-volume composite containers to transport hydrogen. Before RSPA can grant or deny an exemption request, it needs to conduct the necessary research and analysis to determine whether the product provides for an equivalent level of safety as the HMR and is in the public interest. These factors are the only grounds for granting or denying exemptions.

RSPA's Office of Pipeline Safety is working with DOE on safety requirements and a safety review of DOE R&D, including solicitations for new hydrogen transport technologies, innovative pipeline designs, materials, sensing technologies, and containers. Developing safety codes and standards for hydrogen storage systems and interface technologies is critical for sustained development of a hydrogen economy. New codes and standards will be functional, systems-oriented, based on sufficient and comprehensive factual knowledge including statistically-appropriate experiential data. These new technical standards cannot limit the development and commercial introduction of new innovative technologies.

RSPA is charged with promoting the harmonization and alignment of the HMR with international standards. In keeping with this charge, RSPA represents the U.S. on international regulatory bodies and Standards Developing Organizations governing hazardous materials transportation. RSPA's technical staff will continue to participate in these activities and conduct R&D in partnership with DOE and DOE national laboratories, other Federal agencies and industry groups. These activities will provide the technical basis for the development of national and international consensus safety standards for the safe transportation of hydrogen.

### ***Safety of Infrastructure and Vehicle Technologies***

RSPA and other DOT Operating Administrations contribute to the technology goals of a hydrogen economy by leading efforts to develop and demonstrate vehicle and infrastructure safety technologies, including hydrogen fuel cells for all classes of vehicles.

DOT will support DOE in the evaluation, verification and implementation of the infrastructure safety technology developments needed to ensure the safety of the hydrogen infrastructure. Potential examples include:

1. Evaluation of transportation storage and delivery infrastructure safety concepts;

2. Material selection and safety performance of high pressure and cryogenic hydrogen containers and pipelines;
3. Safety verification and validation of fracture and failure modes analysis; and
4. Development of risk management/integrity plans for hydrogen transmission and distribution pipelines.

The National Highway Traffic Safety Administration (NHTSA) is the DOT Operating Administration responsible for promulgation of vehicle safety and fuel economy standards and regulations. NHTSA leads the U.S. delegation at the United Nations Economic Commission for Europe (UNECE) World Forum for Harmonization of Vehicle Regulations, including safety, emissions, and fuel efficiency regulations for all types of road vehicles. In support of the President's Hydrogen Fuel Initiative, NHTSA will identify and conduct critical R&D tests at the component, subsystem, and full vehicle levels to assess system safety and vehicle crashworthiness. With respect to Corporate Average Fuel Economy (CAFE) issues, NHTSA will analyze and evaluate the technical feasibility and practicability of hydrogen vehicles in meeting the maximum feasible fuel economy level. NHTSA will also assess the rulemaking requirements to amend and expand the existing hydrogen Gasoline Gallon Equivalent (GGE) rule to include fuel cell vehicles. This work is necessary because the introduction of alternative fuel vehicles such as hydrogen could significantly alter the level at which NHTSA sets fuel economy standards for light trucks and passenger cars.

DOT is building a base for multimodal operational safety testing and evaluation of emerging hydrogen infrastructure technologies. The Federal Transit Administration's (FTA) advanced technology bus programs are helping to lead the introduction of fuel cells and vehicle technologies into broader transportation applications. Similarly, the Federal Railroad Administration (FRA) and Maritime Administration (MARAD) are leading efforts to integrate hydrogen power into the rail and maritime systems. Both FRA and MARAD hydrogen activities are leveraging DOE initiatives with industry to transition certain technologies from basic and applied R&D toward demonstration and deployment, moving closer to the consumer environment.

### ***Safety Education and Outreach to Foster the Acceptance of New and Emerging Technologies***

Popular support for hydrogen-powered vehicles will require an effective public education and outreach program on hydrogen safety. RSPA can provide effective safety education and outreach to ensure public confidence in hydrogen-fueled vehicles by applying FTA experience in fuel cell fleets and experience acquired by RSPA's Transportation Safety Institute in Hazardous Materials Training.

RSPA plans to partner with DOE, the National Association of State Fire Marshals and DOE's HAMMER Training and Education Center to develop and deliver hydrogen safety training. RSPA will also include hydrogen safety education as part of RSPA's University Transportation Centers Program, and in conjunction with the Federal Highway Administration's regional, state and local networks programs.

RSPA, in coordination with other DOT Operating Administrations, will support DOE efforts to structure and deliver appropriate education and outreach materials. In particular, as part of the interagency plan with DOE, RSPA will establish a partnership program for operational validation, safety education and outreach, fostering public confidence in the safety of hydrogen vehicle systems and infrastructure. As part of this effort, RSPA will work with DOE to implement the safety training materials as part of the Fleet Demonstration Program, support our incubator efforts on training programs and manage a "train the trainer" program to provide industry and others with hydrogen-related information, and deliver safety training to the broader transportation and hazardous materials communities.

### **Intra/Inter-Agency And Partnership Collaborations**

To better respond to the President's Hydrogen Fuel Initiative and provide a mechanism for coordinating the Department's efforts, RSPA has established a DOT Hydrogen Fuels Working Group. The Working Group is aimed at coordinating and identifying synergies in the regulatory, policy, safety, codes and standards, and other research activities ongoing within DOT. The Working Group promotes effective interface and collaboration with other Federal agencies, including DOE, with industry and the public. RSPA also supports DOT's roles in the International Partnership for the Hydrogen Economy (IPHE). RSPA is a member of the IPHE Implementation Liaison Committee and supports the Secretary's Policy Office as Co-chair of the Steering Committee.

RSPA represents the Department on the Hydrogen Fuels R&D Interagency Task Force under the auspices of the White House Office of Science and Technology Policy. Through this forum, Federal agencies coordinate hydrogen-related R&D, codes and standards, and other activities in support of the President's Hydrogen Fuel Initiative. In 2003, the participating agencies on the Task Force, including DOT and DOE, developed an interagency plan to document current and future governmental efforts to develop domestic and international codes, standards and regulations to support the Hydrogen Fuel Initiative. The plan provides a framework for participating agency collaboration on research to support the development of safety codes and standards for advanced vehicle and infrastructure technology development. DOT's Operating Administrations, in partnership with DOE, other government agencies and industry will implement the interagency plan.

RSPA is also DOT's Steering Team member in the California Fuel Cell Partnership (CaFCP). The CaFCP was formed in 1999 and has grown to become a voluntary collaboration of 30 partners comprised of auto manufacturers, energy providers, technology companies and government agencies. During 2004 - 2007, the CaFCP will continue to demonstrate fuel-cell powered electric vehicles under real day-to-day driving conditions; test alternative fuels; demonstrate the viability of alternative fuel infrastructure technologies; explore the path toward commercialization; and increase public awareness of fuel cell electric vehicles. The Partnership is working to facilitate placement of up to 300 fuel cell passenger vehicles and fuel cell buses on the road by the end of 2007 and will build more fueling stations in California. DOT/RSPA is working with the CaFCP to ensure that a strong safety ethic prevails. RSPA is encouraging the development of more robust operating data and lessons-learned documentation to provide

government with the information needed to evaluate the safety of a hydrogen infrastructure and the vehicles it supports.

### **Concluding Statement**

The President's Hydrogen Fuel Initiative holds much promise. It can strengthen the Nation's energy security and reduce emissions that contribute to air pollution. Realizing the vision of a hydrogen economy will require a long-term commitment, cooperation among Federal agencies, and public-private partnership investment in finding solutions to an array of technical, societal, economic and institutional challenges related to safety.

To enable successful introduction of hydrogen and fuel cells into the marketplace, the development of harmonized global technical codes, standards and regulations providing high levels of safety and environmental protection should proceed in parallel with technology development. This process will assist to ensure consumer confidence and maximize industry investment in hydrogen technologies and products.

DOT, working closely with DOE and other stakeholders, can help ensure that the President's Hydrogen Fuel Initiative is safe. DOT is conducting appropriate R&D to reduce the likelihood of an incident and will prepare local communities and emergency responders for appropriate action should an incident occur. Further, DOT is working to close any gaps between continuing advances in technology and corresponding regulations to provide for the safe use of these technologies without slowing progress on the President's Hydrogen Fuel Initiative.